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Description

Ball Apparatus Having Adaptive Rotational Inertia

Cross Reference to Related Applications

[0001] This Application is based on U.S. Provisional Patent Application, Serial No. 60/481,296, filed 27 August 2003.

Background of Invention

Field of Invention

[0002] The present invention relates to a novel ball apparatus (ball), such as one which may be used as a golf ball. More specifically, the ball is one which advantageously exhibits gyroscopic rotational-inertia-self-tuning (GRIST) capabilities. More particularly, the ball apparatus is formed with an inner core having displaceable members, such that the ball□s rotational inertia remains adaptive to a force imparted thereto.

[0003] A number of the advantages realized by a ball apparatus formed in accordance with the present invention may be

more clearly illustrated with reference to such exemplary applications as that of a golf ball. In the game of golf, it is universally desired that balls struck with a club travel consistently far and, at the same time, accurately. It is true that, in general, the harder one hits a golf ball the farther it goes. But the equipment one uses also plays a very significant role in this. With the aid of technologically improved golf clubs and golf balls, driving distances have invariably improved considerably over the years.

[0004] As far as golf balls are concerned, they are subject to restrictions set by the United States Golf Association (USGA) for official play in tournaments or other competitive activities. It is highly unlikely that any major manufacturer would make significant investment in the manufacture and marketing of nonstandard golf balls, that is, balls which do not meet USGA guidelines. Therefore, the USGA approved golf balls are, practically speaking, the only kind of balls readily available in the market.

[0005] Two of the five USGA specifications for golf balls translate into limitations on the golf ball's size and weight. A ball may only weigh up to 1.62 ounces and must measure no less than 1.68 inches in diameter. The remaining three USGA golf ball specifications are as follows. First, when

the golf ball is hit by a set club head speed on a USGA specified machine, the initial velocity of the ball must not exceed 250 ft/s with a 2% tolerance (that is 255 ft/s maximum). Second, when the ball is struck with a USGA specified driver at a club head speed of 160 ft/s and a launch angle of 10 degrees (as tested by the USGA), the ball's overall distance cannot exceed 280 yards with a 6% tolerance (or a maximum of 296.8 yards). Lastly, the ball must pass the USGA administered symmetry test, which requires the ball's flight to remain consistent in distance and trajectory no matter how the ball is placed on a tee.

[0006] Naturally, all top quality golf ball manufacturers make their golf balls to perform as close to the maximum speed and distance limits set by the USGA as possible. That is not to say that all golf balls behave similarly. Even if they may travel roughly the same distance when struck by a club head having a speed of 160 ft/s, differently manufactured balls may travel widely different distances when hit by a club head having faster or slower speeds. Also, the spin, feel, and consistency of the ball are major factors which vary significantly with golf ball designs.

[0007] Spin, in particular, creates a major problem in golf ball research. For certain types of golfers, and for certain types

of situations, a low-spin golf ball is desirable. For example, the ball may spin too much when a strong, hard-hitting golfer hits it from a tee using a driver/wood club. This adversely creates too much backspin that tends to keep the ball from rolling or bouncing forward when it lands, and therefore suppresses the total drive distance. On the other hand, for golfers hitting the ball softer, or for iron shots where the ball is expected to land on the green (approach shot), more backspin is essential for the ball to "stick" better on the green.

[0008] These divergent yet equally prevalent needs of the □long□ and □short□ games prompt manufacturers to produce golf balls with a variety of favors. Unfortunately, prevailing golf rules typically require the use of the same golf ball for each hole (unless it is lost, in which case penalty strokes are incurred). There are no golf balls heretofore known which possess the spin properties concurrently befitting both the long and short games.

[0009] Indeed, golf balls are made, nowadays, with a wide variety of different types, materials, and styles to suit various golfing styles and various situations. In particular, there are high-, medium- and low-spin golf balls designed for almost every type of golfer in every different scenario. Al-

most invariably, though, a low-spin golf ball is called for at the tee-off stage, while a higher spin one is desired at the approach shot stage. Moreover, USGA rules specifically forbid switching a golf ball in the middle of a hole (except if it is irretrievable)! No single golf ball on the market today adequately satisfies such needs at both stages of play.

[0010] Other than versatile spin properties, another desirable feature that an ideal golf ball should possess is straightness in trajectory, without loss of the controllability which permits an experienced golfer, when necessary, to still make draw and hook shots with the ball. While many high quality golf balls produced nowadays claim to be straighter than others, there are none heretofore known which provide a suitable combination of straightness and controllability.

PRIOR ART

[0011] There is an enormous amount of interest in the field of golf balls. Golf balls with higher than average moment of inertia for decreasing the spin rate are known. Examples of such are provided by US Pat. 6,315,681 (M. J. Sullivan, 2001, "Perimeter Weighted Golf Ball with Visible Weighting") and US Pat. 6,110,058 (J. E. Bennett, 2000, "Golf Ball Structured Primarily for Putting" for a "Terradynamic Ball"

with higher moment of inertia and without dimples). Other references introduce new materials into golf balls such as silicon (US Pat. 6,162,134) and gel particles (US Pat. 6,186,906). But there are only a handful, other than those directed generally to liquid-interior golf balls, which disclose movable parts inside a golf ball.

[0012] Liquid interiors were first introduced to improve the feel of a golf ball when being struck. Other variations, such as using "non-aqueous liquid" (US Pat. 6,514,157, Jordan et al.), have been proposed as well. Some even claim that the liquid interior "golf balls can obtain a gyro moment ...[thus] the rate of spin is stabilized, the angle of fall becomes flat relative to the ground, travel distance is extended, and the straightness of the ball's trajectory is improved" (in US Pat. 5,984,805, Maruko). Any such liquid-derived gyro effect is necessarily weak since it relies only on friction and viscosity of the fluid inside to develop a higher effective moment of inertia. This is far from sufficient to be of any practical significance in many applications.

[0013] Other references are known which disclosed movable parts inside golf balls. They include US Pats. 728,311 (1903) and 737,031 (1903). In the first one, H. M. Singer

discloses a hollow globe/center in the golf ball, where one or more smaller ball(s) are introduced into the globe region. Those little balls are free to move inside the globe. The reference discloses such [golf] balls to run longer or travel farther, but offered no physical explanation. In fact, such internal structure will have little predictable positive effect on a ball's travel distance, or on a ball's behavior in general. The disclosed structure is more akin to a rattling toy for infants or pets, than anything else.

[0014] The latter reference, by W. M. Short, is a slight modification of the previous one. Instead of a hollow globe, the golf ball is designed with a hollow tubular ring with a number of smaller balls free to move within. It is claimed that (a) the flight of the ball may be improved, (b) the "pitch" may be better controlled, and (c) a "drag" may be given to the ball in putting. Again, no physical explanation is offered. Moreover, this device is even less useful because the tubular ring makes the golf ball highly unlikely to pass the current USGA symmetry test. In any case, such devices with internal movable parts fail to disclose any changing moment of inertia for adaptively controlling the spin rate, nor do they produce any consistent gyroscopic effects.

[0015] U.S. Pat. 3,331,605 (1967) by R. C. Special is directed to a "Golf Ball Including Diametrical Concentrated Weight Plane", wherein a fixed torus/ring (disc with a hole) is embedded inside a golf ball. While such a toroidal element may bring some gyroscopic stability to the ball's flight, it necessarily compromises any hope of the ball satisfying the USGA symmetry test. Note that such golf ball requires a special mark to be carefully printed on it so that the toroidal plane can be aligned with the intended line of the golf drive. Even if the USGA symmetry rule were disregarded, such a golf ball is in no way desirable. The fact is that one can possibly reach the green from the tee with a single drive only on the par-3 holes. Before the ball reaches the green, it cannot be picked up for realignment. As a result, if such golf ball is used, most likely it will not be properly aligned except for the tee shot or after it reaches the green. The asymmetric weighted ball without proper alignment will result in vigorous wobbling, severely and detrimentally affecting the control of subsequent golf shots. What is more, there is no moving part inside such golf ball; therefore, its moment of inertia will not change, much less be adaptive to certain factors.

[0016] In another reference found at the webpage

http://mb-soft.com/public/gyroball.html (Feb 2000), the author C. Johnson proposes a "gyroscopic golf ball" with a pending patent. The reference discloses a ball in which the gyroscopic effect is indeed strong when properly aligned; however, the Johnson□s ball also suffers from a number of the shortcomings addressed in preceding paragraphs.

[0017] Other references known in the art include: US. Pat. 3,908,993 in the field of baseball/softball, US. Pats. 4,121,828 and 5,462,491 in bowling, and US Pats. 4,923,196 and 5,228,687 in American football. These references either describe ways to increase/decrease the moment of inertia of the game ball in a permanent fashion, or disclose adding elements anisotropically to obtain a gyro moment. None of these references, however, discloses game balls with internal moving parts, or a changing, adaptive moment of inertia.

SUMMARY OF INVENTION

[0018] It is a primary object of the present invention to provide a ball apparatus having a rotational inertia adaptive to a force imparted thereto.

[0019] It is another object of the present invention to provide a ball apparatus which adaptively exhibits gyroscopic prop-

erties when set in motion.

[0020] It is yet another object of the present invention to provide a ball apparatus which exhibits versatile spin properties suitable for various applications and uses thereof.

[0021] It is still another object of the present invention to provide a ball apparatus which enables a user to impart a path of travel thereto in a highly controlled manner.

[0022] In an exemplary application, a plurality of weight members - realized as beads, for example - slide along guide members - realized as rods/rails, for example - radially extending from the center of the ball apparatus. As the ball apparatus spins, the beads are displaced away from the center in anisotropic fashion. The beads near the ball apparatus rotation axis remain close to the center while those near the equatorial plane displace radially outwards. The beads distribution tends to approach in shape a spinning horizontal gyro/disc, the physical effect of which is to significantly improve the straightness and consistency of the ball apparatus resulting trajectory.

[0023] Another novel effect of the moving beads is as follows. When the ball apparatus spins or rolls at a fast rate, the beads tend to move outward, consequently increasing the moment of inertia (a more widely used term for rotational

inertia) of the spinning ball apparatus. The physics of angular momentum conservation dictates a responsive decrease in the spin rate when that happens. On the other hand, when the ball apparatus spins or rolls at a slower rate, the moment of inertia tends not to increase as much; thus, the ball apparatus tends to spin faster. Even for different shots - in the exemplary golf ball application - which impart differing degrees of spin-generating force to the ball, a much more consistent spin rate may then be realized for the ball.

[0024] In accordance with the present invention, the ball apparatus may take the form of various game balls that are spherical, with the game balls usually spinning or rolling, such as in bowling, tennis, baseball, softball, billiard and other such applications. The ball apparatus may also take the form of various game balls that are non-spherical game, such as in applications like American football, for example, where rods extending cylindrically outward from a central axis to realize many of the advantageous effects specifically disclosed herein.

[0025] In the exemplary gyroscopic rotational-inertia-self-tuning (GRIST) golf ball embodiment disclosed, the ball apparatus is formed with an inner core and a plurality of beads.

These beads enable the "self-tuning" by their radial displacement as the ball spins. The resulting golf ball structure provides numerous advantages. First, the moment of inertia of the golf ball changes with the spin rate. If the ball attempts to spin faster, the increase in moment of inertia will decrease the spin rate; when its spin slows down, the decrease in moment of inertia tends to increase and restore the spin rate. As a result, one gets a more consistent spin rate regardless of how hard or soft the ball is hit. From the tee shot to the approach shot, one will benefit from such adjustable spin rate without changing the golf ball.

[0026] Second, with the beads kept close to the center when the golf ball is at rest, the initial moment of inertia is low. This minimizes the skidding motion when struck during putting, making the putt more predictable and easier to control.

[0027] Third, as the ball spins, the beads are displaced in anisotropic fashion. The beads around the spinning axis remain close to the axial center, while those at or near the "equator" will be urged outwards the most. This results in a (spinning) disc or donut like distribution of beads. The gyroscopic nature of such a spinning object tends to re-

tain its spinning orientation despite the presence of external forces/torques. In physics terms, this spinning disc tends to preserve its angular momentum rather well. External torques could make the rotational axis precess, rather than tip over, thus preserving its orientation. A better known example in sports may be that of a spiraling American football whose axial spin inhibits wobble; or, a fast-spinning wheel on a bicycle whose spin makes it easier to balance than when they are at rest.

[0028] Such gyroscopic effects of the GRIST golf ball enable a straighter shot even when bounced off inclined fairways. They likewise enable experienced golfers to effect draw and fade shots more precisely, even in windy situations. The straightness of travel also benefits putting, as the slopes and breaks of greens will have minimal influence on the path of putt made with GRIST golf ball, as compared to that of putts made with other standard golf balls.

BRIEF DESCRIPTION OF DRAWINGS

[0029] FIG. 1 is a schematic sectional view showing the interior of a ball apparatus formed in accordance with one exemplary embodiment of the present invention, at a resting state;

[0030] FIG. 2 is a schematic sectional view showing the interior of a ball apparatus formed in accordance with another ex-

emplary embodiment of the present invention, at a resting state;

[0031] FIG. 3 is a schematic sectional view showing the interior of a ball apparatus in the embodiment of FIG. 2, while moving to the right and spinning about a horizontal axis (relative to the plane of the paper);

[0032] FIG. 4 is a schematic sectional view, partially cut away, showing a portion of the interior of a ball apparatus formed in accordance with yet another exemplary embodiment of the present invention, at a resting state; and,

[0033] FIG. 5 is a schematic sectional view, partially cut away, showing a portion of the interior of a ball apparatus formed in accordance with still another exemplary embodiment of the present invention, at a resting state.

Detailed Description

[0034] To ensure the golf ball spins and rolls smoothly, and as well pass the USGA symmetry test in the disclosed golf ball embodiment of the present invention, it is important that the weight members (configured preferably as beads) are distributed as uniformly as possible. With reference to well-known mathematical concepts, if the (discrete set of) beads were to be uniformly distributed on the surface of a sphere, these beads can be viewed as vertices of a poly-

hedron. To achieve a uniform distribution, "regular polyhedrons" (i.e. the faces are also regular polygons, such as equilateral triangles, squares or regular pentagons) are first considered. As a mathematical fact, there are only five of them, which are sometimes called the "Platonic solids". They are: the regular tetrahedron (4 vertices, 4 triangular faces), octahedron (6 vertices, 8 triangular faces), hexahedron (a.k.a. cube, 8 vertices, 6 square faces), icosahedron (12 vertices, 20 triangular faces), and dodecahedron (20 vertices, 12 pentagonal faces). GRIST golf balls with these vertex distributions are termed for purposes of this description: V-4, V-6, V-8, V-12, and V-20 respectively, with the V-number corresponding to the number of vertices.

[0035] The more the beads/vertices, the better the golf ball conforms to the USGA golf ball symmetry specification. Beyond V-20, there are many other highly symmetric distributions. One of them, the V-32, is a combination of the V-12 and V-20 distributions mentioned above. Mathematically, one can construct it by putting a bead on each of the 12 vertices of an icosahedron, and putting another 20 beads at the center of each face, extended radially outwards. The new polyhedron with 32 vertices is left with

60 triangular faces. This process of adding more beads at the center of faces can be carried on indefinitely if desired.

[0036] The 60-face polyhedron obtained above is no stranger to scientists. If we put a bead at the center of each of the 60 faces, we obtain the same configuration as a carbon sixty molecule (also called the bucky ball). Such a golf ball, the V-60, would describe the geometry of a standard soccer ball, with 12 pentagonal faces, 20 hexagonal faces, and 60 vertices. This V-60 configuration (if not the V-12, V-20, or the V-32) should be symmetric and smooth enough to pass the USGA symmetry test. One can nevertheless put even more beads in the GRIST golf ball; however, one would quickly reach the point of diminishing returns - minimal improvement to the symmetry and smoothness of the final product, with disproportionate increase in production costs. The configurations mentioned above are in no way exhaustive; and, one may put any number of beads in the GRIST golf ball, depending on the available resources in the intended application. Primarily, it is just a matter of whether the resulting ball can pass the USGA symmetry test, and how much its production cost would be.

[0037] FIG. 1 shows the interior of the GRIST golf ball embodiment with twelve vertices, that is, a V-12 model. The springs *14* are fully extended, with all the beads *16* pushed towards the center while the golf ball is at rest. FIG. 2 shows an embodiment with twenty vertices, or a V-20 model. Again, the springs *14* are fully extended while the golf ball is at rest. FIG. 3 shows the displacements of the beads *16* at an instant when the V-20 golf ball of FIG. 2 is spinning at a high angular speed.

[0038] Referring to FIG. 2 showing a preferred embodiment of the present invention with twenty vertices, the spherical shell *10* is enclosed by a cover layer *20* (preferably formed with outer dimples) of a typical golf ball. Inside an inner chamber defined by the shell *10*, twenty guide members in the form of rods *12* are attached thereto. The rods *12* are preferably disposed about a core *18* preferably in a uniform fashion, much like the distribution of the twenty vertices of a regular dodecahedron. The rods *12* are extended radially inwards from the shell to, preferably, a soft spherical center core *18*. The center core *18* is being held in position by at least one of the rods *12*. A small bead *16* slidably engages each rod *12* to be disposed between the shell *10* and the center core *18*. A spring *14*, or other re-

silient member, is preferably inserted between the bead *16* and shell *10* on each rod *12*. In the embodiment shown, each spring *14* biases a bead *16* radially inward, capturing it against the core *18* when the ball is at rest, as illustrated in FIG. 2.

[0039] For the purposes of quantitative description, let ω be the angular velocity (rad/s) of a spinning ball, and Θ be the angle that a rod *12* makes with the axis of rotation. In other words, the north pole is defined at 0 degree, the equator at 90 degrees, and the south pole at 180 degrees. A bead *16* (with mass m, a distance r from the center) will experience a centrifugal force with the radial component $F_r = mr\omega^2 \sin^2\Theta$. Assume the beads *16* slide radially at a distance r measured from the center with c<r<R, where c is the radius of the center core *18*, and R is the radius of the shell *10* of the golf ball. Assume further at this point that all the springs *14* used are linear and obey the Hook's law $F_s = -k(r-r_0) = -m\omega_0^2(r-r_0)$, with ω_0 the "natural frequency" of each spring-mass oscillator.

[0040] The sum of the two forces, or to simplify the analysis, the two forces per k (the spring constant), gives $(F_s + F_r)/(m\omega_0^2) = -r(1-\sin^2\Theta\omega^2/\omega_0^2) + m\omega_0^2 r_0$. For a given ω, as Θ increases, the force increases and could become positive.

That means the beads *16* will be pushed towards the outer shell *10*. A more detailed analysis shows that if r_0 is non-positive, the equilibrium point P (with F=0) is unstable. If the bead *16* is beyond the point P, it will be swung towards the outer shell *10*, and if it has not yet reached P, it will still be pulled towards the center core *18*. As a result, the beads *16* will be either at the center, or fully pushed outwards, depending on the initial positions. On the other hand, if r_0 is positive, the equilibrium point P is stable, and the point P moves outwards continuously as ω and/or the angle Θ increases gradually.

[0041] The value r_0 has to be smaller than c, however. This will ensure that all the beads *16* are pushed sufficiently towards the center when the golf ball is at rest. Preferably, a relative value of c/2 is chosen here.

[0042] As for the numerical values for the springs *14* and the beads *16*, the best combination will have the beads *16* start to move outwards when a predetermined spin rate is reached. The predetermined spin rate is preferably the natural frequency ω_0 of the spring-bead combination. If the spin of the ball is such that $\omega >> \omega_0$, most of the beads *16* (except those close to the rotation axis where Θ is small) with $\sin^2\Theta\omega^2/\omega_0^{\ 2} >> 1$ will be swung towards

the outer shell *10*.

[0043] In an actual game of golf, putting with a golf ball rolling without slipping at typical speeds of 2-5m/s translates into spin rates of 15-40 rev/s. Other spin rates vary from 45-70 rev/s for a standard driver shot, to 90-120 rev/s for a 6-iron shot, and to 130-160 rev/s for wedge shots (data obtained from Gary Mayers' Golf Equipment Journal published on http://www.equip2golf.com 2002). Although these seem like a wide range of spin rates, they are nevertheless within a factor of 10. A golf ball formed in accordance with the present invention is advantageously adapted to accommodate such varied ranges.

[0044] In order to obtain the different gyroscopic effects appropriate for both driving and putting, it is preferable to use multi-grade springs. The simplest multi-grade version has each spring *14* formed by two shorter spring sections, preferably of equal length, but with different stiffness parameters k_1 and k_2. One can choose k_1 and k_2 such that ω_1=20 rev/s and ω_2=80 rev/s. At low spin rates occurring during putting, for instance, only the weaker springs are compressed (while the stiffer springs do not participate, relatively speaking). In this scenario, the beads along the equator are extended to about half the length of the rods

12 with the weaker spring fully compressed. The desired gyroscopic effects are thus appropriately obtained. At high spin rates occurring during iron shots, for instance, the stiffer springs also come into play. The entire multi-grade springs around the equator are now fully compressed, thus obtaining the strongest gyroscopic effects only when actually needed.

[0045] In one specific example, the GRIST golf ball is preferably formed with the following exemplary specifications. With the entire GRIST golf ball no heavier than 46 grams (1.62 oz) set by the USGA, the ball apparatus (entire ball without the cover layer *20*) is preferably configured to weigh around 32-40 grams, and typically weighs 36-38 grams in the embodiment shown. With the diameter of the entire GRIST golf ball set to be no less than 1.62 inches, the shell *10* is preferably formed with a diameter of 1.4-1.7 inches, most preferably 1.5-1.6 inches, so that together with the cover layer *20*, the entire ball has a roughly 1.7 inch diameter, which is typical for today's golf balls.

[0046] The outer shell *10*, with an approximate diameter of 1.58 inches, preferably weighs about 2 grams. The core *18*, formed preferably as a rubber center core, has an approximate diameter of 0.3 inch, preferably weighs about 2

grams. The rods *12* each then has a length of about 0.7 inch, and are formed preferably with a combined weight of about 10 grams.

[0047] Each rod *12* extends from the outer shell *10* of the core radially inwards and pinches into the center core *18*. The springs *14*, each with a natural length of 0.72 inch, preferably carry a combined weight of about 4 grams. All the beads *16* have a combined weight of about 20 grams. These give a total weight of about 38 grams.

[0048] In one example of a V-20 model of the GRIST golf ball, each bead *16* preferably weighs, for example, about 1 gram; each rod *12* preferably weighs about 0.5 gram; and, each spring *14* preferably weighs about 0.2 gram. Each spring *14* is preferably formed from two or more sections having different stiffness parameters k. The two k-values are preferably 0.4 and 6.4 Newton/meter, so that the two corresponding natural frequencies are approximately 20 and 80 rad/s, respectively.

[0049] The various portions of the GRIST golf ball disclosed may be formed of any suitable materials known in the art, as the present invention is not limited to any particular choices of such. The actual choice of materials will de- pend on the specific requirements of the intended appli-

cation, and the practicability of their use in light of the prevailing materials and manufacturing technologies.

[0050] The gyroscopic nature of the resulting golf ball provides a straight stable golf shot, and with controlled spin properties that suit virtually any golf shot: long and short drives, as well as putts. While the above description contains many specifics, these should not be construed as limitations on the scope of the invention, but rather as an exemplification of various preferred embodiments thereof. The dimensions, sizes and weights of the components can be altered in any suitable way one prefers, as may be appropriate for the intended application. Among other things, the stiffness of the springs can be changed to fine tune the golf ball□s performance. Also, any number of vertices may be incorporated, so long as they provide sufficient distribution to enable compliance with the USGA symmetry test, if the given golf ball is to be used in tournaments or other competitive play.

[0051] In an exemplary alternate embodiment of the present invention, two or more separate springs may be used on each rod *12* instead of one composite multi-grade spring. As illustrated in FIG. 4, a shorter but stiffer spring *15*, which coils coaxially around a portion of a longer, weaker

spring *14*. When the ball is set in motion, the bead *16* at first presses on the weaker spring *14*, compressing it to a point where the bead *16* finally touches the shorter, stiffer spring *15* if the ball□s spin is great enough. The effective spring constant increases after that point to produce roughly the same effect as a one-piece multi-grade spring *14* mentioned above.

[0052] In another exemplary alternate embodiment, the springs *14* are disposed and configured to draw, or pull, its corresponding bead *16* radially inward when the ball is at rest. As illustrated in FIG. 5, each spring *14* is disposed between the center core *18* and the beads *16*, and coupled thereto. Each spring *14* is compressed when relaxed, and stretch outwards as the golf ball spins to resiliently bias the ball towards the core *18*.

[0053] In yet other exemplary alternate embodiments, springs *14* having multi k-values integrated therein, or springs *14* having a continuous change in stiffness along its length may be used. The relative lengths of the spring components having different k-value may be varied as desired in those alternate embodiments to effect heightened control at certain different spin rates.

[0054] In still other exemplary alternate embodiments, the cham-

ber region inside the shell *10* may be filled with liquid or a gas rather than just air, provided that the total weight of the ball is accordingly adjusted so that the entire ball will not be excessive in weight for the intended application. The actual fill liquid or gas may be suitably selected in light of the prevailing requirement in the intended application.

[0055] In another exemplary alternate embodiment, each guide member *12* is formed not as a rigid rod, but as a string segment pulled taut, preferably between the core *18* and shell *10*. Fishing lines or other such string materials of suitable strength and material properties known in the art may be used. The flexibility of the string sections allows them to accommodate deformations of the golf ball (to the extent permitted by its overall structural configuration) without breakage when the ball is subjected to great impact, e.g. when the ball is being hit off the tees.

[0056] During typical use of the exemplary GRIST golf ball embodiments specifically described herein, the numerous small beads *16*, or weight members, provided within the golf ball may independently slide radially along the fixed rod guide members *12* also provided inside the golf ball. These beads *16* are resiliently biased towards the center of

the golf ball by little springs *14* when the ball is at rest. The advantages of this structure include the following:

[0057] 1. It is common physics knowledge that the greater the weight dispersed on an outer edge, the higher the moment of inertia and the lower the spin rate. Normally, when a golf ball is struck hard, it tends to spin quite fast. The faster it spins, the harder the beads in the disclosed GRIST golf ball are pushed towards the perimeter by "centrifugal force", thus increasing the moment of inertia and reducing the spin rate. This causes the GRIST golf ball to perform much like a low-spin golf ball found in today's market for hard-hitters. On the other hand, when the golf ball is struck softly, the beads remain closer to the center, thus yielding a smaller moment of inertia. The ball then tends to spin faster. This causes the GRIST ball to perform much like a high-spin golf ball. The GRIST golf ball thus exhibits a widely consistent spin rate, regardless of how hard it is being hit.

[0058] 2. As the GRIST golf ball travels and spins during its flight, the beads located at or near the axis of rotation or spin (that is, closer to the "north/south pole") experience very little "centrifugal force", and thus tend to remain close to the center. The beads located at or near the plane per-

pendicular to the axis of rotation (or around the "equator") experience maximal "centrifugal force", and thus tend to gravitate toward the outer edge. As a result, the beads□ distribution is anisotropic during the ball□s flight. Instead of spreading out uniformly towards the surface of the golf ball, they adaptively distribute themselves to substantially describe in shape of a disc with its plane vertical.

[0059] The golf ball will therefore exhibit gyroscopic behavior. In particular, the axis of rotation and the spinning plane will be more stable against external factors such as wind. Unpredictable (bad) hops will also be minimized when the ball bounces. The strong gyroscopic effect will tend to keep it traveling straight even when bounced off slopes inclined sideways. The result is simply a very straight golf shot.

[0060] Experienced golfers may still use their advanced skills to hit a draw or fade shot with the GRIST golf ball, if necessary. In other words, experienced golfers can give the golf ball an initial spin whose rotation axis not exactly horizontal, but tilted away therefrom. As the gyroscopic effect tends to keep the spinning orientation more stable even in strong wind, a more controlled draw or fade shot results.

[0061] 3. The GRIST golf ball is also well suited for putting on a

green. In situations where a long putt is needed, for example, a golfer must strike the ball harder than usual. Because the ball is typically hit right at (or very close to) the center by a putter (with 0-3 degree loft), the ball will receive a translational impulse without any rolling at first. This causes the ball to slide and skid initially. Eventually, frictional forces cause the ball to begin, then continue rolling without slippage on the green.

[0062] The initial skidding causes a putt to be less predictable, and also slows down the ball more than if it were rolling smoothly (kinetic friction vs. static friction). Ideally, if a golf ball is hit above its center by the proper amount (as determined by the radius of gyration), it will immediately start rolling smoothly without sliding. That would require putters with reverse loft. Although such putters have been proposed (US Pat 5,928,088), they are difficult to use in practice, as they obscure alignment with the golf ball, and render it more likely to be double-hit.

[0063] This notwithstanding, if the mass of the ball were concentrated at the center (zero moment of inertia), the ball would begin rolling instantly when struck at its center with an ordinary putter. In general, the lesser the moment of inertia, the easier the ball will roll. The GRIST golf ball,

with its beads initially concentrated at the center, possesses minimal moment of inertia when initially struck by a putter. Even when an ordinary putter without reverse loft is used, the GRIST golf ball tends to begin rolling smoothly sooner than other golf balls heretofore known. As a result, the path of the ball becomes more predictable and easier to control.

[0064] 4. In putting, one of the more difficult tasks is to "read" the green. A professional golfer is trained to read the slopes/inclinations as well as the dryness/wetness of the green, and to predict how all these factors affect the path of a putt. Advantageously, as the GRIST golf ball rolls on greens, its gyroscopic nature will result in a straighter putting path, more resistant to the otherwise detrimental inconsistencies and inclinations of the terrain. This affords the user a larger margin of error in reading the green. Therefore, the GRIST golf ball enables one□s putting to become more consistent.

[0065] Although this invention has been described in connection with specific forms and embodiments thereof, it will be appreciated that various modification other than those discussed above may be resorted to without departing form the spirit or scope of the invention. For example,

equivalent elements may be substituted for those specifically shown or described, certain features may be used independently of other features, and in certain cases, particular combinations of features may be reversed or interposed, all without departing from the spirit or scope of the invention as defined in the appended Claims.